# The ENSO and QBO impact on ozone variability and stratosphere-troposphere exchange relative to the subtropical jets

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## Introduction

The upper troposphere/lower stratosphere (UTLS) composition around the sub-tropical jets (STJ) is highly variable. At least a portion of regional tropospheric ozone variability around the STJs have previously been attributed to El Niño Southern Oscillation (ENSO) and Quasi-Biennial Oscillation (QBO) induced changes in stratosphere troposphere exchange (STE) around the jets. However, the jets are highly variable in their location, including an influence from ENSO (see Manney et al. poster #16). In addition, large horizontal and vertical gradients exist across the jets. Using a jet-based coordinate system can reduce much of the apparent composition variability associated with the jet movement, sharpen the gradients, and highlight distinct air masses. In this study, we use Goddard Earth Observing System Data Assimilation System (GEOS DAS) analyses of OMI and MLS ozone data mapped to a STJ coordinate to examine the influence of ENSO and QBO on global and regional variability of UTLS ozone and STE associated with tropopause-folding. The STJ coordinate system maps the ozone analyses relative to the horizontal and vertical distance from the jet cores in the Northern and Southern Hemispheres. Multiple linear regression is used to give the spatial distribution of the variance and sensitivity of UTLS ozone that is uniquely attributable to the QBO and ENSO time series relative to the STJ in both hemispheres.

## Data and Methods

GOES-5 Data Assimilation

- We assimilate total column ozone from OMI, stratospheric profiles from MLS, and meteorological data into GEOS-5 spanning 2005 through 2013.
- 2° x 2.5° Lat-Lon for this analysis. Here, we use monthly means.
- Ziemke et al. (2014) and Wargan et al. (2015) evaluated the analyses tropospheric ozone. Olsen et al. (2016) used the analyses to examine the spatially-resolved tropospheric column ozone (TCO) response to ENSO.

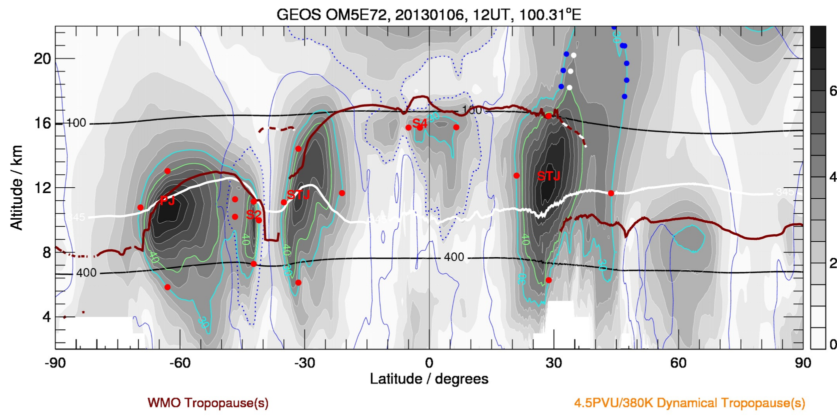
STJ Coordinate

- Ozone analyses are placed into coordinate system using 0.5 km vertical and 2° latitude resolution.
- Negative coordinate values indicate distance below and degrees south of jet cores.

Multiple Linear Regression With ENSO and QBO Indices

- Niño 3.4 Index
- QBO: 50 hPa wind speed and direction.
- We use monthly mean, deseasonalized time series of ENSO, QBO, and ozone.

## Jet Characterization (See also Manney et al. poster #16)



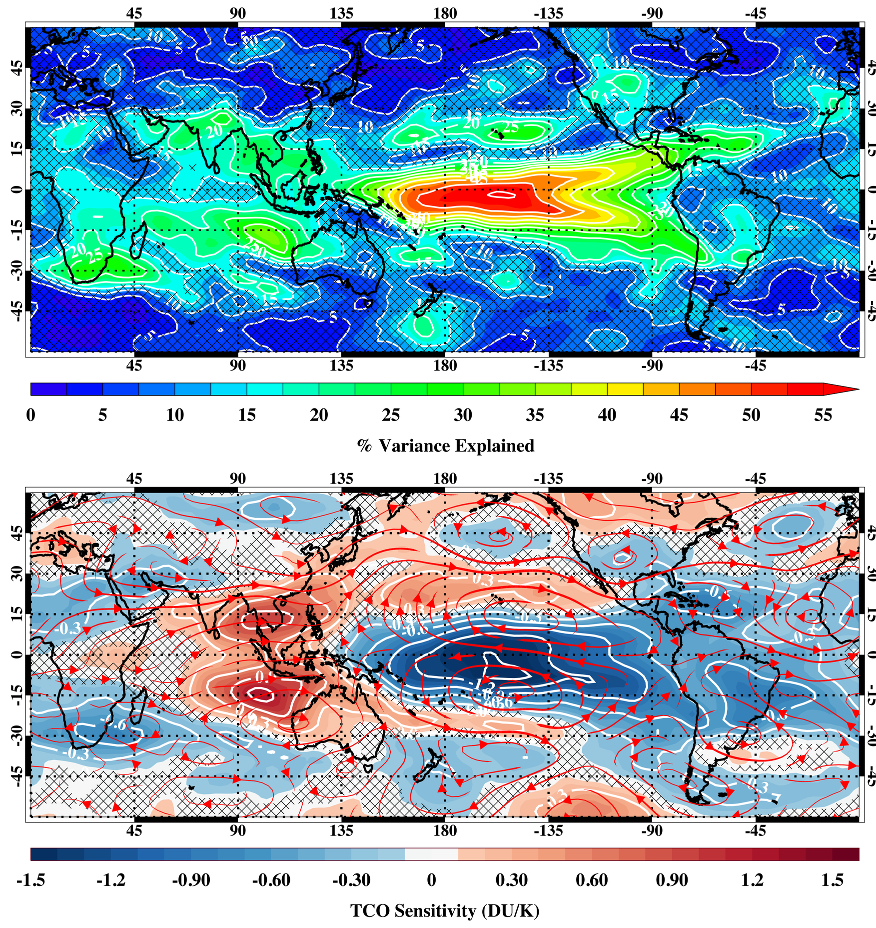

After Manney et al. 2011

- Jet cores: windspeed maxima greater than 40m/s
- Jet region edges: windspeed 30m/s
- Subtropical jet (STJ): Lowest latitude westerly jet with tropopause altitude > 13km at its equatorward edge and a tropopause drop >2.5km between equatorward and poleward edges

**References:**

- Manney, G. L., et al. (2011), Jet characterization in the upper troposphere/lower stratosphere (UTLS): applications to climatology and transport studies, Atmos. Chem. Phys., 11, 6115-6137, doi:10.5194/acp-11-6115-2011.
- Olsen, M. A., et al. (2016), Tropospheric column ozone response to ENSO in GEOS-5 assimilation of OMI and MLS ozone data, Atmos. Chem. Phys., 16, 7091-7103, doi:10.5194/acp-16-7091-2016.
- Wargan, K., et al. (2015), The global structure of upper troposphere-lower stratosphere ozone in GEOS-5: A multiyear assimilation of EOS Aura data, J. Geophys. Res. Atmos., 120, 2013-2036, doi:10.1002/2014JD022493.
- Ziemke, J. R., et al. (2014) Assessment and applications of NASA ozone data products derived from Aura OMI/MLS satellite measurements in context of the GMI chemical transport model, J. Geophys. Res. Atmos., 119, 5671-5699, doi:10.1002/2013JD020914.

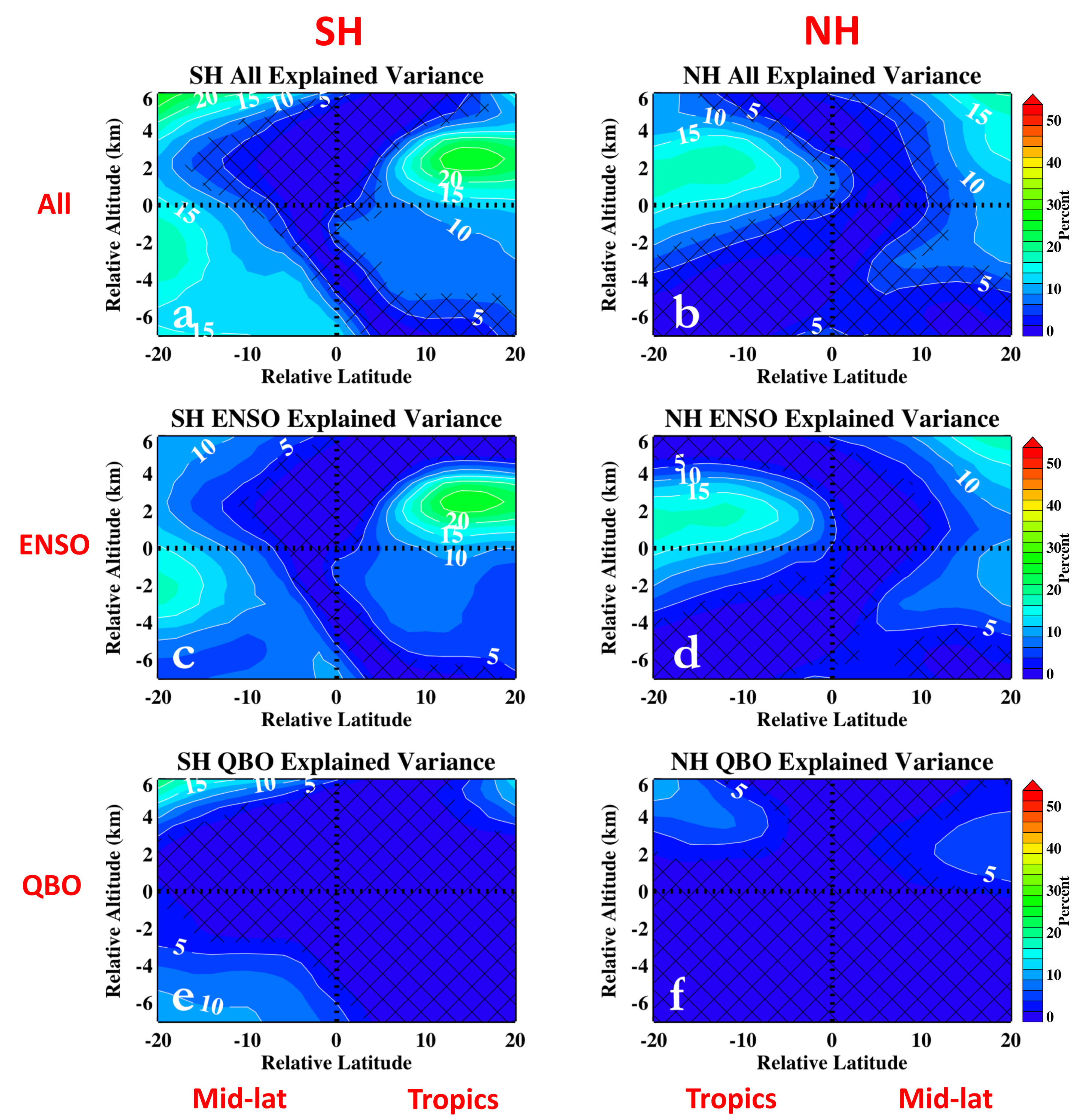
## ENSO Impact on Tropospheric Column Ozone (TCO)




- Percent variance explained by ENSO (top) and sensitivity to ENSO (bottom).
- Red streamlines are difference in winds for strong El Niño months – strong La Niña months.
- Influence of ENSO on subtropical TCO and STJ evident, particularly in the Pacific.
- ENSO influence in the subtropics suggests impact on stratosphere-troposphere exchange associated with the STJ.

(Figures in this panel from Olsen et al., 2016)

## % Variance Explained by ENSO and QBO; All Longitude




Cross-hatched where not significantly different from zero

- Globally, the explained variance by the QBO is much less than ENSO around the STJ.
- Hints at impact on stratosphere to troposphere transport (greatest in SH) but is very weak.
- The attribution between the QBO and ENSO is reasonably separated with generally less than 5% of the explained variance being "confounded".

## Published Paper

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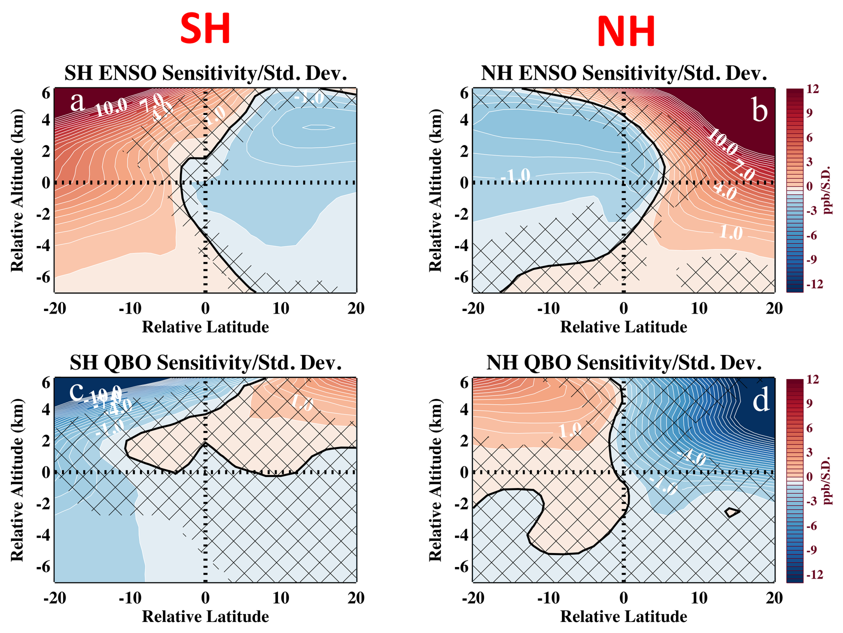
## Ozone Sensitivity to ENSO and QBO; All Longitude Mean

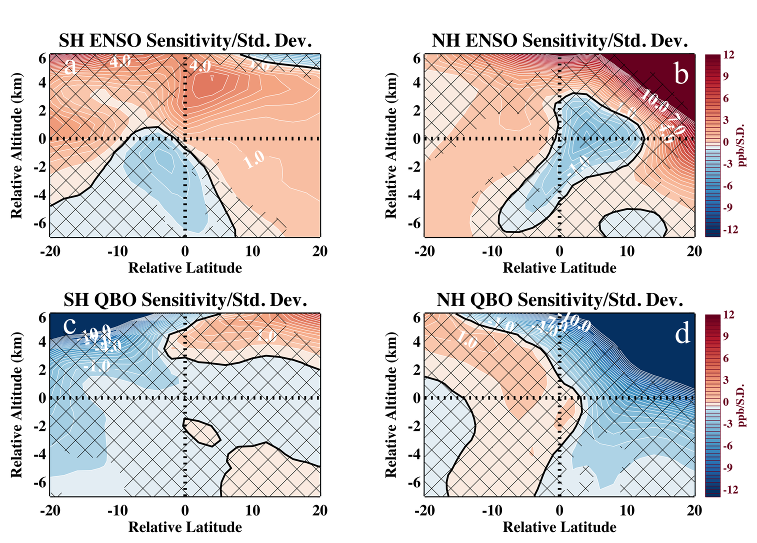



- Evidence of a slight increase in tropopause folding/STE during El Niño conditions.
- No apparent influence of QBO on STE.
- In general, the QBO and ENSO sensitivities are opposite in sign and of comparable magnitudes (relative to one standard deviation). Thus, they can largely cancel or reinforce the response depending on their relative phases and magnitude.

Plotted as change in mixing ratio (ppb) per ± one standard deviation of the ENSO or QBO time series.

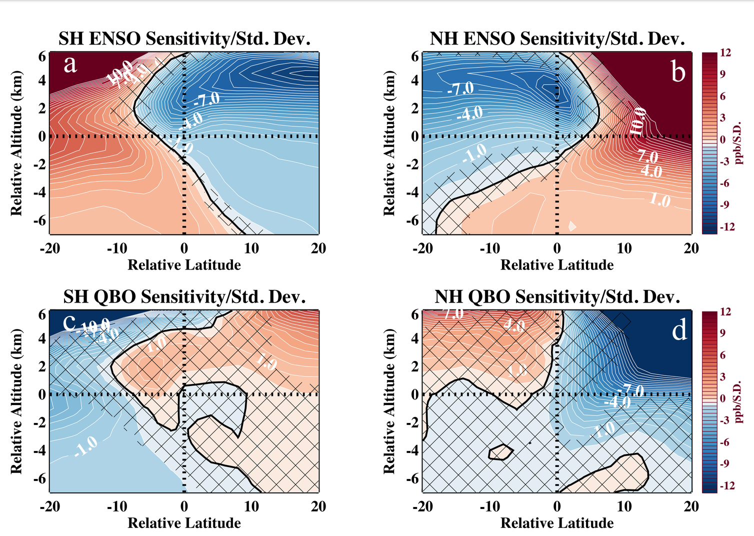
## Regional Variance Explained and Sensitivity

SH NH



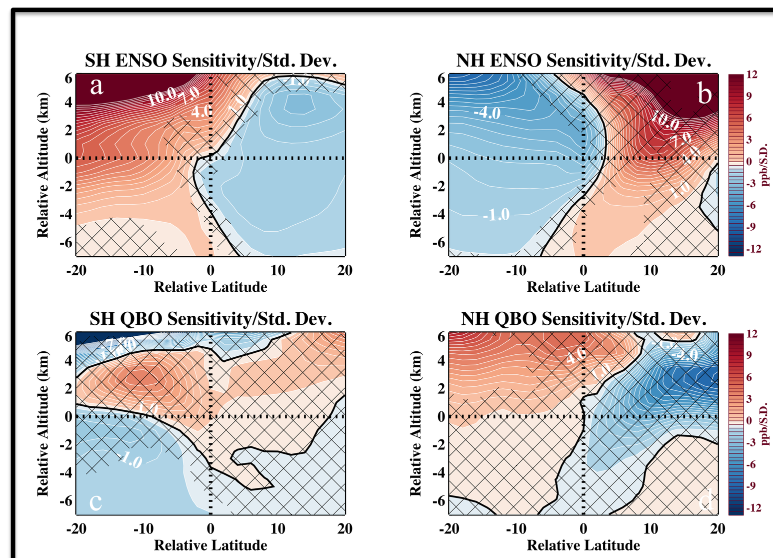
### 90° E to 135° E

- Positive sensitivity equatorward of the STJ consistent with increased ozone during El Niño due to more biomass burning in the region. Its vertical extent indicates this increased ozone lofted to tropical UTLS.
- Very little influence by QBO in troposphere but strong impact in the midlatitude lower stratosphere.



### 180° W to 135° W

- Region of greatest impact on folding/STE by both ENSO and QBO.
- Up to ~20% of the variance is explained around the tropopause on the poleward side of the NH STJ and up to ~40% of the SH STJ. (not shown here).
- Again, the sensitivities indicate ENSO and QBO can greatly cancel or reinforce the response.



### 90° W to 45° W

- Impact from ENSO in the Caribbean/Atlantic.
- Greater than 25% variance explained by ENSO on the equatorward side of the NH STJ at the altitude of the jet. Greater than 20% variance explained by ENSO on the equatorward side of the SH STJ (not shown here).

## Summary

- Globally, ENSO dominates the ozone response around the STJ compared to the QBO. The impact is greatest in the midlatitude lower stratosphere and tropical upper troposphere.
- There is evidence of a positive correlation of folding/STE to ENSO on the global scale but both the sensitivity and explained variance is small.
- The influence of both ENSO and QBO is greater when considering smaller regions, although the QBO influence remains small below the altitude of the STJ.
- Over much of the area around the STJ, the ENSO and QBO influence can greatly cancel or strongly reinforce, depending on their relative phases.
- Results are useful for comparing modeled QBO and ENSO influences on ozone variability that removes the first-order impact of differences due to the location of the STJs.